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INFLUENCE OF THE DISTANCE OF THE CHROMATOGRAPHIC ANALYSIS POINT ON THE ENERGY FLOW CALCULATION IN GASBOL

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ABSTRACT

In Bolivia-Brazil Gas Pipeline the gas samples are only taken in two points along in its all extension, the first is located just at the entrance of the gas pipeline in Rio Grande, Bolivia, and the second sampling point is 550 km far from the first, exactly on Brazil's border, where the pipeline comes to the TBG's property. In Brazilian ground, the pipeline has no more additional inlet point and after this point in the border, no more any additional samples are taken.

Nowadays, the measurement process has been simplified by the use of the gas composition analyzed in the day of the sampling as exactly the same gas that is filling out the whole gas pipeline at that moment. This simplification creates a mistake that is expected, but until then it had not been calculated.

The present paper has an objective to identify the sampling point influence in the energy delivered in TBG´s city gates. To have a better analysis of this influence it is necessary to calculate the gas residence time from the border to the specific delivery point. This residence time is determined by simulation.

Considering the difference among the energy used in the revenue and the energy calculated by the new gross heating value adjusted by the residence time of the gas, this paper concluded that the influence of the sampling point in the calculation of the delivered energy is small because the variation of the gross heating value along the period has also been low.

1. INTRODUCTION

The Bolivia-Brazil Gas Pipeline (GASBOL) is a 32-inch gas pipeline, with a total extension of 3,159 kilometers (1,963 mi) and a rated operating pressure of 100 kg/cm^2g (1,422 psig), extending from the gas producing fields of Rio Grande, Bolivia, to Canoas, Brazil. It is the largest gas pipeline in Latin America.

The Bolivia-Brazil Gas Pipeline Brazilian portion is owned and operated by Transportadora Brasileira Gasoduto Bolívia-Brasil S.A., TBG, a company whose shareholders are Petrobras, El Paso, ENRON South America, Shell, Total Fina, BG Group and Transredes S.A.

TBG was created from a Brazilian Federal Government program, which had the objective to increase the natural gas participation in the Brazilian energy matrix from its low 2%

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share in 1997, to 12% in 2010. In July of 1999 TBG started its first business operations delivering gas to Guararema (São Paulo) and in March of 2000 the whole pipeline was ready to work.

In 2000, when the basic project was concluded five compressor stations were built: one in Bolivia, and four in Brazil. Three of these compressor stations, one in Bolivia and two in the Northern portion of the pipeline in Brazil, use 4 Solar Taurus 60 gas turbines and MHI - Mitsubishi Heavy Industries - 3V-2 centrifugal compressors. The other two stations, in the Southern Brazil, use Nuovo Pignone reciprocating compressors driven by gas engines.

In July of 2003, TBG achieved the goal to increase the Pipeline’s transportation capacity to 30 million cubic meters per day (1059 MMCFD). Eleven new compressor stations were built, eight of them in Brazil. Each new Brazilian compressor stations have two Solar Mars 100 gas turbines driving 5V-3 MHI - Mitsubishi Heavy Industries - centrifugal compressors.

Nowadays 19 million cubic meters per day (671 MMCFD)in average are being transported by TBG, This amount represents 50% of the Brazilian market consumption. Presently the natural gas participation in the Brazilian energy matrix is 7,5 %.

In 2004, TBG has 36 City-Gates, plus one transfer station – the Guararema Measurement Station in the State of São Paulo, where the Pipeline reaches southeast net of pipelines operated by with the Petrobras Transporte S.A. - Transpetro. Those pipelines supply the Greater São Paulo, Rio de Janeiro and Minas Gerais with Bolivian natural gas and Brazilian natural gas from the off-shore platforms.

Figure 1 – Bolivia-Brazil Gas Pipeline

From its Head Office in Rio de Janeiro, TBG controls all the Pipeline’s operations along its entire length of 2,593 kilometers on Brazilian soil. It surveys the full extension of the Pipeline 24 hours a day, by satellite, utilizing a SCADA system.

The maintenance of the Pipeline’s installations is a responsibility of the three Operational Divisions: West, located in Campo Grande, covering the State of Mato Grosso do Sul; East, located in Campinas, servicing all the State of São Paulo; and South, located in Florianópolis, in charge of the States of Paraná, Santa Catarina and Rio Grande do Sul.

2. OBJECTIVES

This paper has an objective to identify the influence of the sampling point in the calculation of the delivered energy in TBG´s city gates. To have a better analysis of this influence it is necessary to calculate the gas residence time from the border to the specific delivery point. This residence time is determined by simulation.

The results give an opportunity to compare the installation and maintenance chromatographic costs with the financial benefits obtained in minimizing errors in the delivered energy calculation.

3. METHODOLOGY

The historical data of gross heating value and daily volumes received in the border were collected in the period between July of 1999 and December of 2002. The first operational days in 1999 were not considered because this period had great variations in delivered volumes; many stations were in a start-up period.

Each city-gate measures the volume of gas consumed (m³) and this volume is converted in energy (BTU) by using Gross Heating Value (BTU/m³). Nowadays, the Gross Heating Value considered in the calculation of the energy in the city-gate is the same value that had already been calculated at the border.

It were chosen four city-gates with representative characteristics of all other stations in order to observe the influence of the Gross Heating Value variation in the energy delivered.

City-gates chosen in this paper:

- ✓ Campo Grande: located to 415 km of the border, it is the closest station to the border and it assists a thermo electrical unit;

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- ✓ Rio Claro: located to 1.200 km of the border, it is the first station of São Paulo state and it represents a regular consumption profile;
- ✓ Guararema (Measurement Station): located to 1.413 km of the border, it is the point of the biggest amount of gas delivered in this pipeline, approximately 50% of all gas transported by TBG goes to this point. Here is the interconnection with the southeast net of Transpetro.

- ✓ Canoas: located to 2.440 km, it is the most distant station of the border.

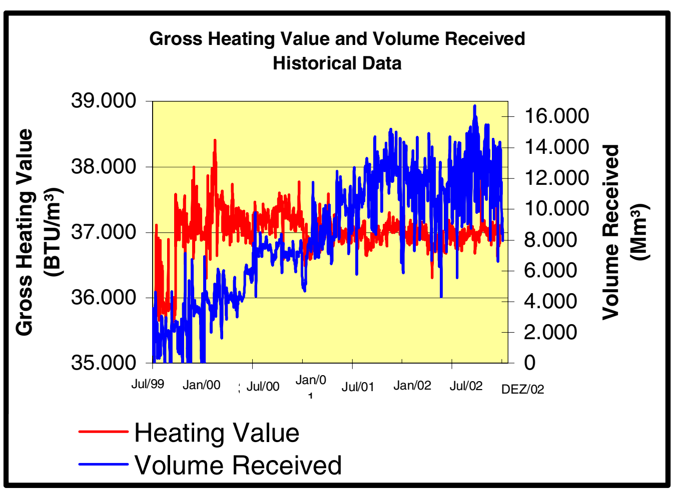
Simulations were done to find the gas average speed along the pipeline. Once estimated the speed for each scenario, and known the distances between the border and the delivery points it can be established the gas residence time in the whole pipeline. The simulation software employed in this study was Pipeline Studio of ESI. The simulations were accomplished for five different transport capacity scenarios of 10, 15, 20, 25 and 30 MMm³/d.

The new energy values were recalculated using new gross heating values adjusted in function of the residence time. The results were compared with the values of energy that had been used for revenue in that time.

4. RESULTS

4.1.Variation profile of Gross Heating Value and Total Volume Received in the Border

In Graph 1 there is a growth tendency in the volume received, but the heating value presents a tendency to stay in a central value along the time.



Graph 1 – Heating Value and Volume Received from Bolivia (Historical Data)

4.2.Gross Heating Value – Averages

Table 1 shows the Heating Values historical data and its averages since 1999, as well as the global standard deviation that it represents 1,00% of the global average value.

In both Graph 1 and Table 1 it can be observed a great variation from 36.000 to 37.000 BTU/m³ in the Heating Value. It happened just at the GASBOL operational beginning. However, this value was stabilized in average value of 36.950 BTU/m³.

Gross Heating Value - Average (BTU/m³)												
	1999			2000			2001			2002		
	Average	Std Dev	%	Average	Desv. Pad	%	Average	Desv. Pad	%	Average	Desv. Pad	%
Jan				37.109	304	0,82	36.747	145	0,39	36.997	118	0,32
Feb				37.593	389	1,03	36.872	126	0,34	36.995	100	0,27
Mar				37.302	207	0,55	37.002	150	0,41	37.010	90	0,24
apr				37.186	225	0,61	37.080	166	0,45	36.800	126	0,34
may				37.145	143	0,38	36.967	101	0,27	36.794	127	0,35
jun				37.012	119	0,32	36.973	99	0,27	36.948	169	0,46
jul	35.860	550	1,53	37.237	93	0,25	36.964	88	0,24	36.887	82	0,22
Agu	36.018	276	0,77	37.204	112	0,30	36.905	174	0,47	36.913	97	0,26
Set	36.193	649	1,79	37.195	119	0,32	36.919	113	0,31	36.947	110	0,30
Out	37.116	215	0,58	37.356	205	0,55	36.968	81	0,22	37.066	197	0,53
nov	37.143	306	0,82	37.246	121	0,32	37.062	122	0,33	37.020	67	0,18
dec	37.149	232	0,62	37.188	137	0,37	37.072	58	0,16	37.016	145	0,39
Annual Average	**36.580**	**694**	**1,90**	**37.231**	**239**	**0,64**	**36.961**	**151**	**0,41**	**36.950**	**148**	**0,40**
	Global Average				**36.979,79**				**%**			
	Global Std. Dev.				**373,18**				**1,009**			

Table 1 – Heating Value Historical Data

4.3.Residence Time

Table 2 shows simulation results of the proposed scenarios. In this table a strong reduction in Residence Time with an increase transport capacity can be observed in pipeline. This reduction is higher where the distance is farther from the border.

Deliver Points	City-Gate Campo Grande		City-Gate Rio Claro		Measurement Station Guararema		City-Gate Canoas	
Distance (km)	415		1.200		1.413		2.440	
Transport Flow (MMm³/d)	<v> (m/s)	RT (dia)	<v> (m/s)	RT (dia)	<v> (m/s)	RT (dia)	<v> (m/s)	RT (dia)
10,00	2,80	1,7	2,24	6,3	2,33	7,1	1,05	27,3
15,00	3,94	1,2	3,37	4,2	3,65	4,6	1,03	27,7
20,00	4,82	1,0	4,34	3,3	4,78	3,5	4,08	7,0
25,00	6,07	0,8	5,32	2,7	6,07	2,7	4,69	6,1
30,00	7,71	0,6	6,67	2,1	7,66	2,2	4,68	6,1

Table 2 – Gas Average Speed and Residence Time

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In Table 2, the expressive decrease in residence time from 28 to 6 days in Canoas is why it is completely necessary operate south compression stations in order to reach the total transport capacity of the gas pipeline (30,00 MMm3/d).

4.4.Errors Calculation

The error is the difference between the energy recalculated and the old energy calculated at that time. Thus, a negative error means that the energy value used in revenue is larger than the energy delivered before. A positive value represents revenue smaller than the officially recognized at that time.

In Tables 3, 4, 5 and 6 are shown the accumulated errors in each year, and the global average error for each transport scenario and for each city-gate chosen in this study. All of the calculated errors were very low.

In These Tables the financial cost of these errors is also presented. The price of the Bolivian commodity considered in this paper is US$ 3,40/MMBTU.

In Guararema station, despite of the fact of the small errors, the volume delivered at this point is very high when it is compared with the other stations. This is why that the financial cost of this error at this point is also very high.

Campo Grande						
Flow	10 MMm³/d			15, 20, 25 e 30 MMm³/d		
month/year	Error	%	US$	Error	%	US$
Total/01	-289,62	-0,006	-984,72	-256,979	-0,005	-873,73
Total/02	208,64	0,003	709,38	-94,756	-0,002	-322,17
TOTAL	-80,983	-0,001	-275,34	-351,735	-0,003	-1195,90

Table 3 – Campo Grande

Rio Claro												
Flow	10 MMm³/d			15 MMm³/d			20 e 25 MMm³/d			30 MMm³/d		
month/year	Error	%	US$	Error	%	US$	Error	%	US$	Error	%	US$
Total/01	-247,318	-0,015	-840,88	-148,965	-0,009	-506,48	-139,976	-0,008	-475,92	-105,694	-0,006	-359,36
Total/02	-171,615	-0,002	-583,49	-106,328	-0,001	-361,51	-79,636	-0,001	-270,76	-47,875	-0,001	-162,78
TOTAL	-418,933	-0,004	-1424,37	-255,293	-0,003	-867,99	-219,611	-0,002	-746,68	-153,570	-0,002	-522,14

Guararema												
Flow	10 MMm³/d			15 MMm³/d			20 e 25 MMm³/d			30 MMm³/d		
month/year	Error	%	US$	Error	%	US$	Error	%	US$	Error	%	US$
Total/99	-21793,150	-0,250	-74096,71	-14587,050	-0,170	-49595,97	-8938,880	-0,100	-30392,19	-6182,640	-0,070	-21020,98
Total/01	-7361,194	-0,013	-25028,06	-3981,941	-0,007	-13538,60	3524,744	0,006	11984,13	5884,153	0,010	20006,12
Total/01	-2458,509	-0,003	-8358,93	-984,619	-0,001	-3347,70	-1204,054	-0,001	-4093,78	-98,566	0,000	-335,12
Total/02	2392,227	0,003	8133,57	-412,222	0,000	-1401,56	962,339	0,001	3271,95	460,124	0,001	1564,42
TOTAL	-29220,620	-0,010	-99350,11	-19965,840	-0,009	-67883,86	-5655,850	-0,002	-19229,89	63,070	0,000	214,44

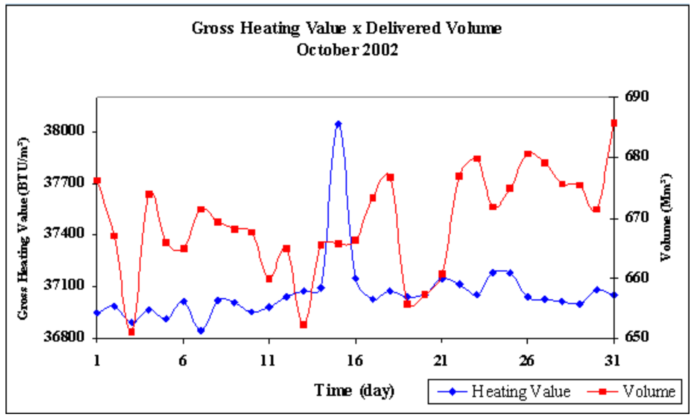
Tables 4 and 5 – Rio Claro and Guararema

Canoas												
Flow	10 MMm³/d			15 MMm³/d			20 MMm³/d			25 e 30 MMm³/d		
month/year	Error	%	US$	Error	%	US$	Error	%	US$	Error	%	US$
Total/00	76,042	0,007	258,54	100,135	0,010	340,46	131,664	0,013	447,66	120,622	0,012	410,12
Total/01	-543,139	-0,010	-1846,67	-647,572	-0,012	-2201,74	-236,208	-0,005	-803,11	-353,960	-0,007	-1203,46
Total/02	872,239	0,016	2965,61	915,417	0,016	3112,42	-54,878	-0,001	-186,58	-24,701	0,000	-83,98
TOTAL	405,143	0,003	1377,48	367,980	0,003	1251,13	-159,421	-0,001	-542,03	-258,039	-0,002	-877,33

Table 6 – Canoas

4.5. Energy Recalculated

As an example it considered data of October 2002. The Graph 2 presents the Heating Value behavior profile and the volume delivered at Rio Claro in this period.



Graph 2 – Rio Claro's Station Historical Data (October 2002)

Graph 3 compares the Heating values of energy delivered in the past with the new values. It shows how a more significant variation in the Heating Value can impact in delivered energy, whenever consider the gas residence time in the pipeline. What is observed in Graph 3 is a displacement of delivered energy peak in function of the postponed use of the heating values of 2, 3, 4 and 6 days. The arrows in Graph 3 mark the displacement observed.

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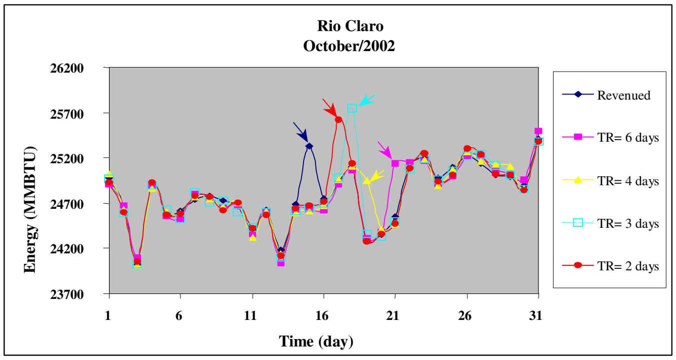

Graph 3 – Rio Claro's Station energy values for different residence times (October 2002)

Associating Graphs 2 and 3, it is observed that the energy delivered profile follows the volume delivered profile. The intensity of the energy delivered peak (residence time of 2 and 3 days) is more significant when the Heating Values follow the Volume delivered peak. When the residence time is 4 and 6 days the Heating Value peak is just at the point where happens a reduction in volume delivered. As a result, the energy value is a less intense peak.

5. CONCLUSIONS

This study certifies that the Gross Heating Values have small variations in average since the beginning of the TBG activities. The standard deviation in 1999 was of 1,90%, and it was reduced for 0,41% in 2001 and kept constant in 2002.

When the energy delivered is adjusted with the residence time it is noticed that this variation has a little influence in the annual totals or in the global total. The errors make no difference along the time.

Taking the residence time as a function of the distance, it can be said that each time corresponds to a different chromatographic sampling point along the gas pipeline. As a consequence, and in function of the small variation of the Heating Value, the impact that the sampling point in the energy values is very small.

Comparing the installation costs of chromatographic equipment, which is of approximately US$ 30.000,00, with the value of the accumulated error, it is concluded that the investment for a correction of this error in TBG's city-gates is not justified. The exception is the Guararema's station. In this case, the higher volumes at this point generate high financial costs for small variations of Heating Values. With the increase of the transport capacity, the residence time will drop and the error will be smaller than now.

Transpetro have already installed chromatographic equipment in Guararema for analyzing gas received from TBG and in city-gates that deliver gas to thermo electrical units, TBG has also installed chromatographic equipments to avoid energy errors.

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